

AP600 Shutdown Evaluation Report Outline

Westinghouse Non-Proprietary Class 3

WCAP-xxxxx Revision 0

AP600 Shutdown Evaluation Report

February 1997

AP600 Document Number: XXX-XXX-XXX

Westinghouse Electric Corporation
Energy Systems Business Unit
P.O. Box 355
Pittsburgh PA 15230-355

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AP600 Shutdown Evaluation Report Outline

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1.0 Introduction

1.1 Background

Discuss how the requirement to provide this report came about.

1.2 Purpose

1. Provide a single source reference to address NRC concerns with AP600 Shutdown Capabilities.
2. Provide a roadmap to information already provided while documenting any additional information required to resolve NRC AP600 Shutdown concerns.
3. Document compliance with NUREG-1449; explain deviations from that guidance.

1.3 Scope

Identified in the following outline.

Documents closure of DSER open items and completion of RAI responses.

Does not address the draft Rule 50.57 for Shutdown but does address shutdown issues of which Westinghouse is aware.

2.0 Systems Designed to Operate During Shutdown

This section describes the important (safety-significant) systems designed to operate during shutdown, including their operating modes during shutdown. Information to be taken from existing documentation.

Each of these sections should provide the following types of information:

2.x.1 System Description

no text other than reference to the appropriate SSAR section
identify as safety-related or nonsafety-related

2.x.2 System Significance for Shutdown

explain what is required to get to shutdown and during shutdown

2.x.3 Conclusion

summarize adequacy to reach and operate at shutdown
tie to plant safety at shutdown

Note: No separate section for Electrical Power Systems or instrumentation discussions - instead, these are to be discussed with each associated system section.

2.1 Reactor Coolant System (RCS)

Define bounding RCS pressure/temperature cooldown profile.

Include ADS and temperature and level instrumentation discussions.

Discuss reactor operations and design features for mid-loop to close DSER OITS items 2291 (same as 2297) and 2293.

To close DSER OITS item 2299, discuss SG nozzle dam design and ties to SG/FWS.

2.1.1 System Description

2.1.2 System Significance for Shutdown

2.1.3 Conclusion

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- 2.2 SGs and Feedwater Systems (FWS)
 - Define secondary side operation in lower modes
 - 2.2.1 System Description
 - 2.2.2 System Significance for Shutdown
 - 2.2.3 Conclusion
- 2.3 Passive Core Cooling System (PXS)
 - 2.3.1 System Description
 - 2.3.2 System Significance for Shutdown
 - 2.3.3 Conclusion
- 2.4 Component Cooling Water (CCS) and Service Water (SWS)
 - 2.4.1 System Description
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 - 2.4.3 Conclusion
- 2.5 Chemical and Volume Control System (CVS)
 - 2.5.1 System Description
 - 2.5.2 System Significance for Shutdown
 - 2.5.3 Conclusion
- 2.6 Normal Residual Heat Removal System (RNS)
 - 2.6.1 System Description
 - 2.6.2 System Significance for Shutdown
 - 2.6.3 Conclusion
- 2.7 Containment Systems
 - Include containment closure status and close of DSER OITS item 2308.
 - 2.7.1 System Description
 - 2.7.2 System Significance for Shutdown
 - 2.7.3 Conclusion
- 2.8 Spent Fuel Pool Cooling (SFS)
 - 2.8.1 System Description
 - 2.8.2 System Significance for Shutdown
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 - 2.9.3 Conclusion

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2.10 Control and Protection Systems (PLS, PMS, DAS)

Define system-level availabilities at lower modes. Describe what parts are required for shutdown and events initiating from shutdown. Discuss T/S change for automatic "S" signal through Mode 4 and requiring a high containment pressure signal through Mode 4.

- 2.10.1 PLS
 - 2.10.1.1 System Description
 - 2.10.1.2 System Significance for Shutdown
 - 2.10.1.3 Conclusion
- 2.10.2 PMS
 - 2.10.2.1 System Description
 - 2.10.2.2 System Significance for Shutdown
 - 2.10.2.3 Conclusion
- 2.10.3 DAS
 - 2.10.3.1 System Description
 - 2.10.3.2 System Significance for Shutdown
 - 2.10.3.3 Conclusion

3.0 Shutdown Operations

Discussion of shutdown risk, shutdown operations, and shutdown ERGs consider that equipment will be taken out of service for maintenance.

3.1 Maintenance Insights

Include RCP maintenance (restart) for Rapid Boron Dilution scenario.
Include specific outage maintenance commitments.
Discuss diesel maintenance.
Describe what requires maintenance at shutdown rather than at-power and say why.
This section does not repeat what is included in the PRA insights.

3.2 Shutdown Risk Management

A discussion of industry planning documents is not included in the scope of this report. A search for insights is the responsibility of the COL applicant. This report contains only those insights of which Westinghouse is currently aware and which are related to AP600 Design Certification. This effort is typically included in the plant Shutdown Risk Management Program.

3.3 Shutdown Emergency Response Guidelines (ERGs) Overview

This is not a step-through, just an overview, philosophy
There don't appear to be any open items regarding the shutdown ERGs (but need NRC closure of shutdown ERGs review so that the SDER is not impacted).
Discuss entry and exit conditions, relationship to other plant procedures, and general differences between shutdown and at-power ERGs.
Mention DSER OITS item 2304, closed by the ERG submittal.

3.4 System/Event Matrix - Confirm continued validity of WCAP-13793 for shutdown-related discussions or note any differences in this section.

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4.0 Safety Analyses and Evaluations

4.1 Introduction to section

Section 4 to address DSER OITS item 2294, review of initiating Chapter 15 events in lower modes.

4.1.1 Matrix of SSAR Chapter 15 Events

Include a matrix of Chapter 15 analyses for various shutdown modes, including those that initiate at shutdown (response to DSER OITS item 2053).

1. Categorize which events are bounded by at-power analyses, which are bounded by current SSAR analyses, which are evaluated for this report, and which are analyzed for this report. For those which require analysis/evaluation, each sections will follow a format like:
Refer to SSAR section for description of events and analysis discussions
Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
Methods/Assumptions
Results/Conclusions
2. Identify and provide brief write-ups in this section for why some events are not an issue at shutdown, as denoted by an N/A in Table 4-1. Examples:

The boron dilution design basis transient explained in SSAR Section 15.4.6 explicitly considers all modes such that no analysis or evaluation is required for this report.

Discussions regarding RCCA withdrawal at power are not applicable to this report since this event occurs only at-power.

4.1.2 Code Adequacy for Shutdown Conditions

Include discussion for adequacy of LOFTRAN-AP, LOFTTR2-AP, NOTRUMP, and WC/T to accurately represent shutdown conditions in the AP600 to close DSER OITS item 1612.

Discuss which code is used for which analyses (i.e., LOFTRAN-AP for transient analyses, LOFTTR2-AP for steam generator tube ruptures, NOTRUMP for small break LOCAs, and WCobra/Trac for large break LOCAs).

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Table 4.1 - AP600 SSAR Accidents Requiring Shutdown Evaluation or Analysis (Preliminary)

15.1	Increase in Heat Removal from the Primary System	
15.1.1	Feedwater System Malfunctions that Result in a Decrease in Feedwater Temperature	E
15.1.2	Feedwater System Malfunctions that Result in an Increase in Feedwater Flow	E
15.1.3	Excessive Increase in Secondary Steam Flow	E
15.1.4	Inadvertent Opening of a Steam Generator Relief or Safety Valve	A
15.1.5	Steam System Piping Failure	A
15.1.6	Inadvertent Operation of the Passive Residual Heat Removal Heat Exchanger	E
15.2	Decrease in Heat Removal by the Secondary System	
15.2.1	Steam Pressure Regulator Malfunction or Failure that Results in Decreasing Steam Flow	E
15.2.2	Loss of External Electrical Load	E
15.2.3	Turbine Trip	E
15.2.4	Inadvertent Closure of Main Steam Isolation Valves	E
15.2.5	Loss of Condenser Vacuum and Other Events Resulting in Turbine Trip	E
15.2.6	Loss of ac Power to the Plant Auxiliaries	E/A
15.2.7	Loss of Normal Feedwater Flow	E/A
15.2.8	Feedwater System Pipe Break	E
15.3	Decrease in Reactor Coolant System Flow Rate	
15.3.1	Partial Loss of Forced Reactor Coolant Flow	E
15.3.2	Complete Loss of Forced Reactor Coolant Flow	E
15.3.3	Reactor Coolant Pump Shaft Seizure (Locked Rotor)	E
15.3.4	Reactor Coolant Pump Shaft Break	E
15.4	Reactivity and Power Distribution Anomalies	
15.4.1	Uncontrolled Rod Cluster Control Assembly Bank Withdrawal from a Subcritical or Low-Power Startup Condition	E
15.4.2	Uncontrolled Rod Cluster Control Assembly Bank Withdrawal at Power	N/A
15.4.3	Rod Cluster Control Assembly Misalignment (System Malfunction or Operator Error)	E
15.4.4	Startup of an Inactive Reactor Coolant Pump at an Incorrect Temperature	N/A
15.4.6	Chemical and Volume Control System Malfunction That Results in a Decrease in the Boron Concentration in the Reactor Coolant	N/A
15.4.7	Inadvertent Loading and Operation of a Fuel Assembly in an Improper Position	E
15.4.8	Spectrum of Rod Cluster Control Assembly Ejection Accidents	E
15.5	Increase in Reactor Coolant Inventory	
15.5.1	Inadvertent Operation of the Core Makeup Tanks (CMT) During Power Operation	E
15.5.2	Chemical and Volume Control System Malfunction That Increases Reactor Coolant Inventory	E
15.6	Decrease in Reactor Coolant Inventory	
15.6.1	Inadvertent Opening of a Pressurizer Safety Valve or Inadvertent Operation of the ADS	E
15.6.2	Failure of Small Lines Carrying Primary Coolant Outside Containment	E
15.6.3	Steam Generator Tube Rupture	E
15.6.5	Loss of Coolant Accidents Resulting from a Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary	E/A
15.7	Radioactive Release From a Subsystem or Component	E

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- 4.2 Increase in Heat Removal from the Primary System (SSAR Section 15.1)
 - Refer to description of events in SSAR.
 - Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.
- 4.2.1 Feedwater System Malfunctions (SSAR 15.1.1 and 15.1.2) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.2.2 Excessive Load Increase (15.1.3) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.2.3 Credible and Hypothetical Steamline Breaks (15.1.4 and 15.1.5) - Analysis
 - Run a case initiated from lower RCS temperatures than cases in the SSAR
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.2.4 Inadvertent PRHR Operation (15.1.6) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.3 Decrease in Heat Removal by the Secondary System (SSAR Section 15.2)
 - Refer to description of events in SSAR.
 - Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.
- 4.3.1 Loss of Load and Turbine Trip (15.2.1 through 15.2.5) - Evaluation
 - Specific evaluation - other SSAR Section 15.2 events to be discussed in 4.3
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.3.2 Loss of ac Power (15.2.6) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions

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4.3.2.1 Loss of Normal RHR (RNS) Cooling in Mode 5 (Condition II) - Analysis

Include Surge Line Flooding evaluation, mid-loop operation evaluation for DSER OITS item 2295 and operator action time to actuate IRWST to address DSER OITS item 2296. This assumes the RCS is intact, except the ADS valves. Does not address whether ADS stage 4 is required.

Show that gravity injection is not prevented once RCS boiling is well established.

Review the relative heights of components. Address reduced inventory operation.

Include ties to Technical Specifications then discuss surge line flooding.

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.3.3 Loss of Normal Feedwater (15.2.7) - Evaluation

This should bound the loss of startup feedwater

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.3.3.1 Loss of Normal Feedwater - Analysis

Run and present a "special" case to confirm cooldown capability of PRHR/IRWST

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.3.4 Feedwater System Pipe Break (15.2.8) - Evaluation

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.4 Decrease in Reactor Coolant Flow Rate (SSAR section 15.3)

Refer to description of events in SSAR.

Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.

4.4.1 Partial and Complete Loss of Flow (15.3.1 and 15.3.2) - Evaluation

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.4.2 RCP Shaft Seizure or Break (15.3.3 and 15.3.4) - Evaluation

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

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- 4.5 Reactivity and Power Distribution Anomalies (SSAR Section 15.4)
 - Refer to description of events in SSAR.
 - Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.
- 4.5.1 Rod Withdrawal from Subcritical (15.4.1) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.5.2 RCCA Misalignment (15.4.3) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.5.3 Inadvertent Loading of F/A in Incorrect Location (15.4.7) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.5.4 Rod Ejection (15.4.8) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.6 Increase in Reactor Coolant Inventory (SSAR Section 15.5)
 - Refer to description of events in SSAR.
 - Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.
- 4.6.1 Inadvertent CMT Operation (15.5.1) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.6.2 CVS Malfunction (15.5.2) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions

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- 4.7 Decrease in Reactor Coolant Inventory (SSAR Section 15.6)
 - Refer to description of events in SSAR.
 - Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.
- 4.7.1 RCS Depressurization/Inadvertent ADS (15.6.1) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions
- 4.7.2 Failure of small lines carrying primary coolant outside containment (15.6.2)
 - Discussion of how shutdown is not a special concern for SSAR Section 15.6.2.
- 4.7.3 Steam Generator Tube Rupture (15.6.3) - Evaluation
 - Refer to SSAR section for description of events and analysis discussions
 - Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)
 - Methods/Assumptions
 - Results/Conclusions

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4.8 Loss of Coolant Accidents (LOCAs) (SSAR Section 15.6.5)

Refer to description of events in SSAR.

Discuss only events are shown in the Section 4.1 matrix to require analysis or evaluation.

This is what is currently planned for evaluation or analysis; adequacy will be determined when analyses are nearer completion:

4.8.1 Large Break LOCA in Mode 3 with no accumulators (Condition IV) - Analysis

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.8.2 Inadvertent ADS Actuation in Mode 3 (Condition III) - Analysis

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.8.3 DVI Line Break in Mode 3 (Condition III) - Analysis

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.8.4 Spectrum of small break LOCAs in lower modes - Evaluation

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.8.5 Loss of RNS cooling with RCS intact (Condition II) - Analysis

Include PRHR.

Refer to SSAR section for description of events and analysis discussions

Evaluation or Analysis for Shutdown Evaluation Report (significance at shutdown)

Methods/Assumptions

Results/Conclusions

4.9 Radiological Consequences (15.7 and Appendix 15A)

Goal is to document that dose releases at shutdown are bounded by Fuel Handling Accident dose analysis; otherwise the containment is closed.

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4.10 Other Evaluations and Analyses

4.10.1 LTOP

This is to be a brief discussion, explaining that LTOP analyses are performed in lower modes, i.e., already evaluated for shutdown.

4.10.2 Safe Shutdown Temperature Evaluation

This is written to address DSER OITS item 2256.

Discuss response to DSER OITS item 2053 for Chapter 15 analyses for various shutdown modes, including those that initiate at shutdown.

Answer the question, "Can we get to safe shutdown temperature with the PRHR."

Address issue of whether or not condensate return is needed.

5.0 Technical Specifications

Refer to previous closure of DSER OITS items 2298, 2300, and 2306.

5.1 Summary of Shutdown Technical Specifications

Include matrix, but for all modes, and overview discussion. This will include reference to the response to RAI 440.58 (to describe what changes in the Tech Specs deal with shutdown operations and to identify and explain any deviations from NUREG-1449 for shutdown Tech Specs).

5.2 Compliance with SECY-93-190

Confirm Tech Spec compliance with SECY-93-190 (DSER OITS item 2053).

6.0 Shutdown Risk Evaluation

Discussion of shutdown risk, shutdown operations, and shutdown ERGs consider that equipment will be taken out of service for maintenance.

6.1 Summary of Shutdown PRA results and insights

Discuss, consistent with section 4.3.2.1, the PRA success criteria which shows ADS Stage 4 is not required and summarize work Westinghouse has done to accommodate this. Reference response for DSER OITS item 3007.

Address DSER OITS item 2309.

Reference Shutdown PRA for vulnerability to loss of offsite power.

Reference transmittals to NRC.

Include shutdown risk evaluation to close DSER OITS item 2053.

6.2 Fire/Flood Risk

Include cross references to SSAR evaluation and PRA Evaluations

Reference and discuss RAI 280.12 (DSER OITS item 3441) and list any other related RAI response references.

Address DSER OITS item 2303.

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7.0 Compliance with NUREG-1449

This is a discussion of AP600 compliance with NUREG-1449 guidance, as applicable to advanced plant design (AP600). This is not a discussion of compliance with all industry issues. List and explain any deviations from NUREG-1449.

This section explains how the work Westinghouse has done, as summarized or documented herein, shows compliance with NUREG-1449 guidance.

This report will be used to respond to RAI 440.53 (DSER OITS item 943).

DSER OITS item 944 refers to numerous RAIs; those applicable to this report will be referenced here.

Include discussion to address DSER OITS item 2292.

8.0 Conclusions

8.1 Closure of Open Items

This section includes a summary for closure of DSER OITS Open Items and completion of RAI Responses related to the AP600 shutdown concerns addressed herein.

943 - A response to RAI 440.53 is drafted but being rewritten. This will be issued as an RAI response which will refer to the Shutdown Evaluation Report and referenced in Section 7.0.

944 - Responses to RAIs 440.54 through 440.72 and 440.168 were issued and provide the technical information. Applicable responses will be referenced in SDER Section 7.0.

1612- There will be a discussion to demonstrate that the AP600 analysis codes, as validated by the testing programs, can be relied upon to accurately represent shutdown conditions in the AP600. See section 4.1.2.

2053- This is closed with 5.0 (Tech Specs), 6.0 (shutdown risk), and 4.0 (events that initiate at shutdown)

2256- This is closed with section 4.10.2

2291- This, for mid-loop operations, will be addressed in Section 2.1.

2292- This will be addressed in the NUREG-1449 discussion, section 7.0.

2293- This (reactor operations for mid-loop) will be addressed in Section 2.1.

2294- Section 4 is written to address this item - a review of initiating Chapter 15 events in lower modes.

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- 2295- This will be closed with the hand-calc for time to boil down from mid-loop to core top and discussion presented in Section 4.3.2.1.
- 2296- This will be closed in Section 4.3.2.1 for operator action time to actuate the IRWST assuming PMS is not working.
- 2297- This item was previously closed. Concerns addressed by open item 2291.
- 2298- This was addressed in the Technical Specifications and will be mentioned in Section 5.
- 2299- This item will be addressed in the RCS System Description section 2.1 (ties to SG/FWS section but SG nozzle dam is on the primary side).
- 2300- This was addressed in the Technical Specifications and will be mentioned in Section 5.
- 2303- This fire protection question will be addressed in Section 6.2.
- 2304 - This was addressed in the ERG⁴ and will be mentioned in Section 3.3.
- 2306- This was addressed in the Technical Specifications and will be mentioned in Section 5.
- 2308- To be addressed in Containment section 2.7.
- 2309- To be addressed in Shutdown Risk section 6.1.
- 3007- This is addressed in NSD-NRC-96-4680 and noted in Section 6.1.
- 3441- RAI 440.33 and closure of item 9.5.1.6-1 of a 6/24/96 NRC letter will be addressed in Section 6.2.

8.2 Conclusion

With respect to AP600 Shutdown Capabilities, this report provides the NRC with everything needed to write the FSER.

9.0 References (sample list)

NUREG-1449, Shutdown and Low-Power Operation at Commercial Nuclear Power Plants in the United States, September 1993.

Docs requesting this report

SSAR sections

ERGs final transmittal

RAI response letters

Tech Spec transmittal

Shutdown PRA transmittal

WCAP-13793, AP600 System/Event Matrix, June 1994.